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Natural Resource Stewardship and Science

Insect Pollinators of Gates of the Arctic NPP

A Preliminary Survey of Bees (Hymenoptera: Anthophila) and Flower Flies (Diptera: Syrphidae)

Natural Resource Report NPS/GAAR/NRR—2017/1541

ON THE COVER

Left to right, **TOP ROW**: Bumble bee on *Hedysarum*, Al Smith collecting bees at Itkillik River; **MIDDLE ROW**: Al Smith and Just Jensen collecting pollinators on Krugrak River, *Andrena barbilabris* on *Rosa*; **BOTTOM ROW**: syrphid fly on *Potentilla*, bee bowl near Lake Isiak

All photos by Jessica Rykken

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Abstract

Insect pollinators, specifically bees (Hymenoptera: Anthophila) and flower flies (Diptera: Syrphidae), are critical to maintaining healthy plant communities and functioning ecosystems in Gates of the Arctic NPP. Despite their ecological importance and potential vulnerability to environmental threats such as climate change, the diversity of these pollinators has remained largely unknown to park staff and visitors. In an effort to establish a pollinator database, I conducted surveys to document bee and flower fly diversity across focal habitats within the park. Field work was conducted from July 2-18, 2015, and June 7-16, 2016. With the help of several assistants, I used an insect net and bee bowls to collect bees and flower flies at 71 sites in selected areas of the park, as well as at several sites outside the park boundary. Sites were located south of the Brooks Range between Walker Lake and the Middle Fork Koyukuk River, and further north in the Brooks Range, from Lake Isiak and the Noatak River in the west, to Oolah Lake and the Itkillik River in the east. Elevations ranged from 179 to 1,176 m. Focal habitats included tundra, lake edges, riparian gravel and sand bars, sandy bluffs, roadsides, and other disturbed areas in the villages of Bettles and Anaktuvuk Pass. In all, we collected 574 bees and 351 flower flies, representing 35 bee taxa and 55 flower fly taxa, several of these represent new records for Alaska. Bumble bees dominated the catch (43% of the total), but we also collected a diversity of solitary and parasitic bees in addition to flower flies. Several pollinator species were collected throughout the park (e.g., *Bombus sylvicola*, *Sphaerophoria abbreviata*), but many species collections were restricted geographically (e.g., south of the Brooks Range) or associated with particular habitats or elevational ranges. Additional surveys and future monitoring are recommended, particularly for species with primarily arctic/alpine ranges. Outreach activities included one pollinator presentation for park staff and visitors at the visitor center in Bettles. A pollinator display for the visitor center at Anaktuvuk Pass is planned, as well as a story map for the park website.

Acknowledgments

Funding for this project was generously provided by the Murie Science and Learning Center, Denali National Park, and the Biological Resources Management Division, Natural Resource Stewardship and Science, National Park Service, Fort Collins, CO.

I am especially grateful to Dave Schirokauer, Jeff Rasic, and Dave Rosser for helping me get to field sites in the park and enthusiastically supporting the pollinator project. DaleLynn Gardener helped with logistics in Bettles, and Al Smith, backcountry ranger at Anaktuvuk Pass, was a wonderful guide, assistant, and companion in the field during both field seasons. Volunteer Just Jensen from Anaktuvuk Pass also helped us out in 2016. Many thanks to Jay and Judy Jespersen and their skilled pilots at Brooks Range Aviation who got me out and back safely to/from all those beautiful and remote places.

As any entomologist knows, most of the work involved in an insect survey is back in the lab, sorting, pinning, labeling, and identifying specimens. Thanks to Andrew Young for taking on the identification of the flower flies. I am also very grateful for the help I received with bee identifications from Jamie Strange, Harold Ikerd, and Terry Griswold at the USDA ARS Bee Biology and Systematics Lab in Logan, Utah; Jason Gibbs at the University of Manitoba; and Paul Williams at the Natural History Museum in London. Kathryn Daly, a graduate student in the lab of Derek Sikes at the University of Alaska Museum, identified the “bycatch” butterflies from our bowl traps in 2016, and Maxim Larrivée, chief entomologist at the Insectarium de Montréal, identified those from 2015.

Thanks also to Derek Sikes for making helpful comments on the content of this report.

Introduction

The vast majority of flowering plants rely on animal pollinators for successful reproduction (Ollerton et al. 2011). Native bees (Hymenoptera: Anthophila) are among the most efficient and diverse insect pollinators, with approximately 4,000 species known in North America (Mader et al. 2011). Another important pollinator group, which includes many bee mimics, is the flower fly family (Diptera: Syrphidae), represented in the Nearctic by approximately 87 0 species (Vockeroth and Thompson 1987). Though comparatively inconspicuous and understudied in Alaskan parks, insect pollinators are critical to ensuring the reproductive success of many of the plants that vertebrate herbivores and omnivores depend upon for survival. Thus, abundant and diverse native pollinator communities are essential for maintaining healthy, functioning wild ecosystems in Alaska.

Pollinators are known to be at risk from various environmental threats such as habitat loss and alteration, invasive pollinator and plant species, parasites and pathogens, pesticides, and climate change (Potts et al. 2010, Goulson et al. 2015). Dramatic declines have been well-documented and publicized for honey bees (Natural Research Council 2006), but have also been seen among native bumble bees (Cameron et al. 2011), and solitary bees (Burkle et al. 2013).Comparatively scant literature exists on the status of flower flies, although changes in species richness and composition pre-and post-1980 have been documented in Europe (Biesmeijer et al. 2006).

In a vast, protected arctic wilderness such as Gates of the Arctic, changing climate is likely the prevailing threat to pollinator communities, with potential consequences including range shifts, decoupling of plant-pollinator networks, and population declines (Bartomeus et al. 2011, Iler et al. 2013, Kerr et al. 2015). We know that the northernmost latitudes are warming and drying more rapidly than any other region on Earth (Serreze et al. 2000) and alarming ecological and physical changes are being seen in Alaska (Chapin et al. 2006). The average annual air temperature in Alaska has increased by 3°F since the 1950’s, a warming trend more than twice as rapid as in the rest of the U.S. (Chapin et al. 2014). The growing season has lengthened by about two weeks, shrubs are invading the tundra and alpine zones, fires are more frequent and intense, and permafrost and glaciers are melting (Stone et al. 2002, Lawrence and Slater 2005, Sturm et al. 2005). Phenological shifts are also occurring at high latitudes; Høye et al. (2007) found advances of an average of 14.5 days per decade across a variety of plant, bird, and arthropod taxa in northern Greenland between 1996 and 2005. Given these dynamic scenarios, it is very likely that pollinator communities in Gates of the Arctic are also responding to landscape-scale changes with spatial and temporal shifts.

In the face of such unprecedented threats, establishing a database of pollinator diversity across various habitats within Gates of the Arctic, especially those that are most vulnerable to effects from climate change (e.g., tundra) is essential, both for a better understanding of current species composition and distributions within park (including rare or endemic species), and as a comparative baseline for monitoring changes in the future. Such a database will also make important contributions to what is known about Alaskan pollinators on a state-wide level, which is minimal given Alaska’s immense area and diversity of landscapes. As an example, ongoing pollinator surveys in Denali National Park (2012-2016) have discovered not only new state records, but also species new to science among the bees and flower flies (Rykken 2015, Williams et al. 2016).

The primary goal of the pollinator survey in Gates of the Arctic was to assess the diversity, distribution, and habitat associations of pollinators (bees and flower flies) in selected areas of the park. It would be logistically impossible and very inefficient to sample across all of the park's 8.4 million acres, so the survey focused on particular habitats known to be productive for pollinators and their host plants (e.g., tundra, gravel bars, sandy bluffs). A second goal was to educate park staff and visitors about native insect pollinators and threats to their health through presentations through presentations, field activities, displays, and online information.

Methods

Study Area

Gates of the Arctic National Park and Preserve comprises 8.4 million acres (approx. 3.4 million ha) above the arctic circle in Alaska. It is the northernmost national park in the United States. Predominant habitat types include boreal or taiga forest at lower elevations and latitudes, and tundra in the north and at higher elevations. Shrub thickets occur along waterways, and wetlands are common at lower elevations and around lakes. Large river systems have extensive gravel bars, interspersed with sandy areas and bluffs.

The flowering season in these arctic landscapes is relatively short, and variable between locations and years, depending on factors such as the severity of the winter, snow melt, exposure, and elevation. Typically, the main blooming season is between late May and mid-July.

Collecting Pollinators

Field work was conducted from July 2-18, 2015, and June 7-16, 2016. With the help of several assistants, I used an insect net and bee bowls to collect bees and flower flies at 71 sites in selected areas of the park, as well as several sites outside of the park (Fig. 1, Table 1). Sites were located south of the Brooks Range in Bettles, along the Koyukuk River, and at Walker and Takahula Lakes; the remaining sites were located further north in the Brooks Range, from Lake Isiak and the Noatak river in the west, eastwards to Chandler Lake, Anaktuvuk Pass, and the Itkillik River. Elevations ranged from 179 to 1176 m. Focal habitats included tundra, lake edges, gravel and sand bars, sandy bluffs, roadsides, and other disturbed areas in the villages of Bettles and Anaktuvuk Pass.

Because almost all species of bees and flower flies need to be examined with a microscope to determine their identity, it was necessary to collect voucher specimens. The survey employed two methods for collecting insect pollinators: aerial nets and bee bowls. Nets allow active sampling of insects while they are in flight, feeding at flowers, or landed elsewhere. Netted specimens were killed with ethyl acetate in collecting jars.

Bee bowls are passive trapping methods that attract pollinators with color (mimicking floral blooms). Bee bowls were set out in transects. Each 145 m-long transect comprised 30 plastic cups (Solo® 3.25 oz.), 10 blue, 10 yellow, and 10 white. The cups were spaced 5 m apart, and were filled 3/4 full with a solution of 2 L water mixed with a few drops of unscented detergent to break the surface tension of the water. Bee bowl transects were generally set out by 10 am and kept open for six or more hours, ensuring that they were open when bees are most actively foraging. At the end of the day, contents (i.e., drowned insects in soapy water) of all 30 bowls from a transect were poured into an 80 mm diameter tight-mesh kitchen strainer. The pooled insect catch from all bowls was then transferred from the strainer into a 4 oz. Whirl-Pak® via a wide-necked plastic funnel. Ethanol (95%) and a locality label were added to the contents before sealing shut the Whirl-Pak®.

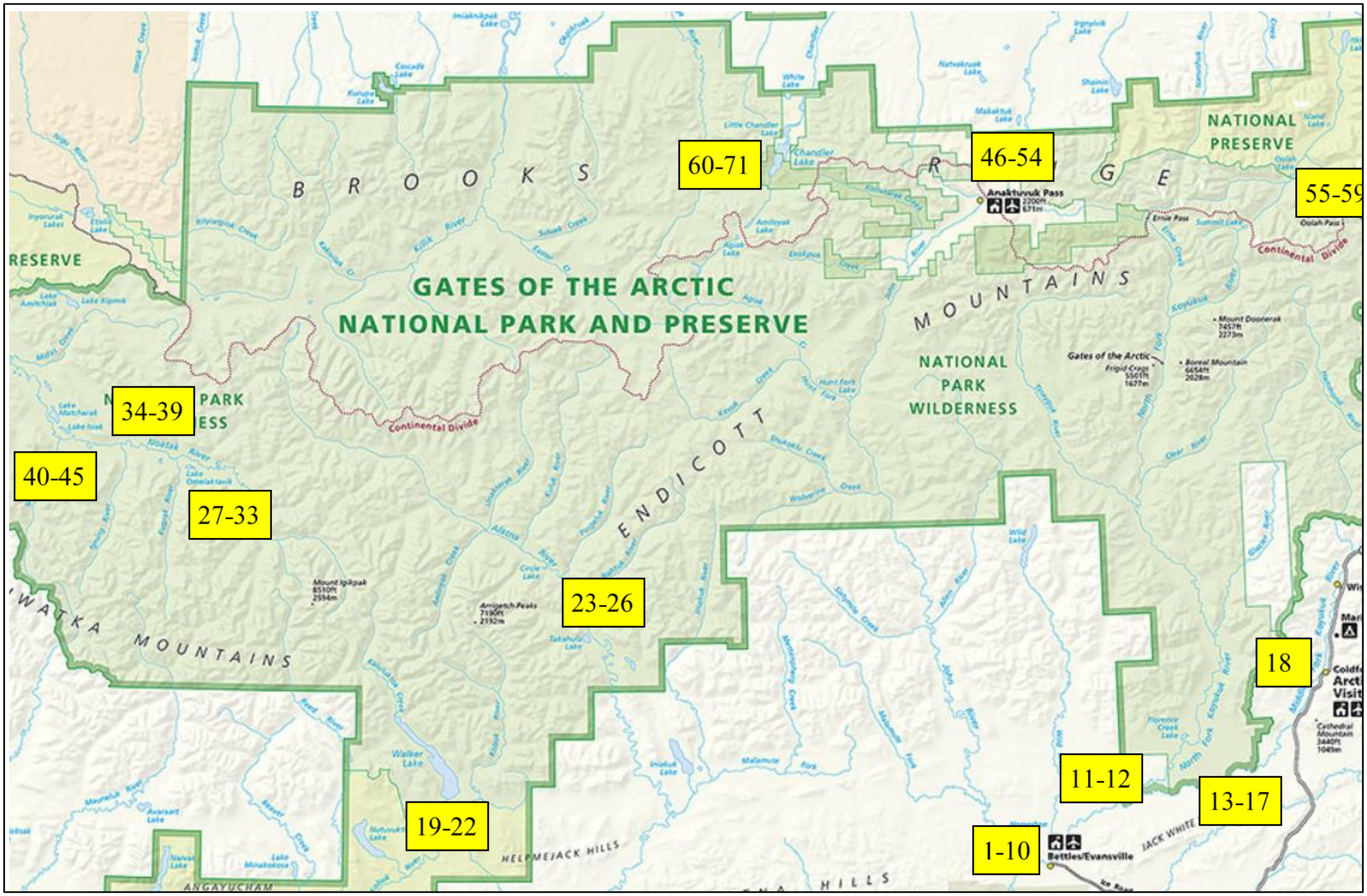

Figure 1. Approximate locations for pollinator sampling sites (see Table 1) located in Gates of the Arctic National Park and Preserve. (Map source: https://www.nps.gov/gaar/planyourvisit/maps.htm)

Table 1. Location, elevation, and general habitat description for 71 pollinator sampling sites in Gates of the Arctic NPP. Types of samples for each site, and dates of collection are shown in last two columns. Site # refers to maps in Figure 1.

Site #	Locality	Lat. (N)	Long. (W)	Elev. (m)	Habitat	Bowl	Net
1	Bettles-Kanuti trail around pond	66.8836	-151.4954	242	tundra	–	7/9/2015
2	Bettles-Kanuti trailhead parking	66.8836	-151.4954	242	roadside	–	7/9/2015
3	Bettles-float pond edge	66.8895	-151.4966	236	lake edge	–	7/3/2015
4	Bettles-near bunkhouse	66.9152	-151.5165	202	lawn	7/5/2015, 6/7/2016	6/7/2016, 6/12/2016
5	Bettles-volleyball field	66.9169	-151.5171	203	disturbed meadow	7/4/2015, 6/7/2016	6/7/2016, 6/12/2016
6	Bettles-road to float pond	66.9169	-151.5171	208	roadside	–	7/2/2015, 7/3/2015, 6/7/2016
7	Bettles-road between river and airstrip	66.9192	-151.5262	185	roadside	–	7/5/2015
8	Bettles-meadow at end of airstrip	66.9202	-151.5200	188	disturbed meadow	7/5/2015	–
9	Bettles-Koyokuk River	66.9214	-151.5248	179	gravel bar	7/5/2015	7/5/2015
10	Bettles-winter access road	66.9225	-151.4989	195	meadow	–	7/5/2015
11	Koyukuk River	66.9828	-151.4311	194	gravel bar	–	6/11/2016
12	Koyukuk River	67.0335	-151.1790	220	sandy bar	6/10/2016	6/10/2016
13	Mid. Fork Koyukuk	67.0424	-150.9074	325	gravel bar	–	6/10/2016
14	Mid. Fork Koyukuk-Roadhouse	67.0438	-150.8050	329	forest	–	6/10/2016
15	Mid. Fork Koyukuk	67.0510	-150.7546	347	gravel bar	6/9/2016	6/10/2016
16	Mid. Fork Koyukuk-Tramway Bar	67.0866	-150.4988	340	sandy bar	–	6/9/2016
17	Mid. Fork Koyukuk	67.1844	-150.3206	369	gravel bar	–	6/9/2016
18	Coldfoot airstrip	67.2498	-150.2118	406	roadside	–	6/8/2016
19	Walker Lake-S shore	67.0627	-154.3220	225	lake edge	–	7/6/2015
20	Walker Lake-S shore	67.0632	-154.3273	265	lake edge	–	7/6/2015
21	Walker Lake-dry ridge	67.0643	-154.3506	225	tundra	7/6/2015	–
22	Walker Lake-S shore	67.0658	-154.3495	224	lake edge	7/6/2015	–
23	Takahula Lake-upland off outlet	67.3441	-153.6427	250	tundra	–	7/4/2015
24	Takahula Lake-S end	67.3454	-153.6625	229	lake edge	7/4/2015	–
25	Takahula Lake-S end	67.3457	-153.6592	214	lake edge	7/4/2015	7/4/2015
26	Takahula Lake	67.3462	-153.6525	235	wetland	–	7/4/2015

Table 1 (continued). Location, elevation, and general habitat description for 71 pollinator sampling sites in Gates of the Arctic NPP. Types of samples for each site, and dates of collection are shown in last two columns. Site # refers to maps in Figure 1.

Site #	Locality	Lat. (N)	Long. (W)	Elev. (m)	Habitat	Bowl	Net
27	Kugrak River	67.6213	-155.6161	548	sandy bluff	–	6/13/2016
28	Kugrak-Not So Warm Springs	67.6237	-155.6211	542	sandy bar	–	6/13/2016
29	Kugrak-Not So Warm Springs	67.6274	-155.6111	542	cottonwood grove	–	6/13/2016
30	Kugrak River	67.6337	-155.6024	570	tundra	–	6/13/2016
31	Kugrak River	67.6621	-155.6076	547	tundra/willow shrub	–	6/13/2016
32	Kugrak River	67.6623	-155.5975	511	tundra	–	6/13/2016
33	Noatak/Kugrak confluence	67.6737	-155.6354	458	gravel bar w/sand	–	6/14/2016
34	Noatak River	67.6873	-155.6655	467	sandy banks	–	6/14/2016
35	Noatak near Igning	67.6949	-155.8307	461	willow scrub	–	6/15/2016
36	Noatak/Igning confluence	67.7013	-155.8829	470	willow scrub	–	6/15/2016
37	Noatak River	67.7064	-156.1243	519	sandy bar	–	6/16/2016
38	Noatak River	67.7070	-156.1252	526	sandy bluffs	–	6/16/2016
39	Noatak River	67.7129	-156.1197	516	sandy bluffs	–	6/16/2016
40	Lake Isiak	67.7137	-156.1342	533	tundra/lake edge	–	6/16/2016
41	Lake Isiak	67.7151	-156.1206	525	tundra	–	6/16/2016
42	Lake Isiak	67.7186	-156.1398	481	tundra	–	6/16/2016
43	Lake Isiak	67.7192	-156.1225	522	stagnant pools	–	6/16/2016
44	Lake Isiak	67.7194	-156.1382	495	wet tundra	6/16/2016	–
45	Lake Isiak	67.7217	-156.1365	499	sandy bluff	6/16/2016	–
46	Anaktuvuk Pass-John River	68.1249	-151.7643	599	gravel bars	–	7/18/2015
47	Anaktuvuk Pass-road to John River	68.1327	-151.7483	612	roadside	–	7/18/2015
48	Anaktuvuk Pass-S end of air strip	68.1402	-151.7293	632	disturbed meadow	7/18/2015	–
49	Anaktuvuk Pass-ranger station	68.1423	-151.7370	634	disturbed area	7/18/2015	–
51	Anaktuvuk Pass-Eleanor Lake	68.1473	-151.7186	642	lake edge/upland	–	7/14/2015
50	Anaktuvuk Pass-Contact Creek	68.1444	-151.7828	689	tundra	–	7/15/2015
52	Anaktuvuk Pass-Contact Creek, lower	68.1478	-151.8114	737	tundra	–	7/15/2015

Table 1 (continued). Location, elevation, and general habitat description for 71 pollinator sampling sites in Gates of the Arctic NPP. Types of samples for each site, and dates of collection are shown in last two columns. Site # refers to maps in Figure 1.

Site #	Locality	Lat. (N)	Long. (W)	Elev. (m)	Habitat	Bowl	Net
53	Anaktuvuk Pass-Contact Creek, at auf ice	68.1549	-151.8308	756	stream edge	–	7/15/2015
54	Anaktuvuk Pass-Contact Creek, upper	68.1619	-151.8659	807	bluff	–	7/15/2015
55	Itkillik River	68.1491	-150.2512	823	river gravel bar	–	7/16/2015
56	Itkillik River-tributary	68.1495	-150.2699	839	river edge/tundra	–	7/16/2015
57	Itkillik River-main stem	68.1500	-150.2500	815	river edge/tundra	7/16/2015	7/16/2015
58	Itkillik River- tributary	68.1501	-150.2727	846	tundra	–	7/16/2015
59	Itkillik River-near Oolah Lake	68.1572	-150.2350	798	tundra	7/16/2015	7/16/2015
60	Chandler Lake-meadows to S	68.1824	-152.7503	885	tundra	–	7/13/2015
61	Chandler Lake-SE slope	68.1887	-152.7457	874	tundra/rocky slope	–	7/13/2015
62	Chandler Lake-S shore	68.1955	-152.7536	865	lake edge/tundra	7/13/2015	7/13/2015, 7/14/2015
63	Chandler Lake-inlet	68.1967	-152.7651	867	stream edge/tundra	7/13/2015	–
64	Chandler Lake-W shore	68.2070	-152.7617	873	dry stream gully	–	7/12/2015
65	Chandler Lake-W shore	68.2115	-152.7626	912	dry stream gully	–	7/12/2015
66	Chandler Lake-NW edge	68.2453	-152.7224	897	lake edge/tundra	–	7/12/2015
67	Chandler Lake-N end	68.2542	-152.7148	887	lake edge/tundra	7/11/2015	7/11/2015
68	Chandler Lake-N end near camp	68.2542	-152.7143	870	lake edge/tundra	–	7/10/2015, 7/11/2015
69	Chandler Lake-N end up NW valley	68.2583	-152.7239	921	tundra	–	7/10/2015
70	Chandler Lake-N end up NW valley	68.2603	-152.7553	1176	tundra/rocky slope	–	7/11/2015
71	Chandler Lake-N end up NW valley	68.2637	-152.7429	950	tundra	7/11/2015	–

Sample Processing and Specimen Identification

Specimens collected dry in nets were pinned on return from field trips at the ranger stations in Bettles and Anaktuvuk Pass. Wet specimens from bee bowls were stored in ethanol in Whirl-Paks® as explained above. At the end of each field season, these wet samples were mailed back to the lab for further processing. Bees and flower flies were extracted from the samples and pinned. Bees were first washed in soapy water and then blow-dried with a hand-held hairdryer according to methods described in The Handy Bee Manual (Droege 2015). All remaining arthropod "bycatch" (e.g., wasps, ants, other flies, beetles, true bugs, butterflies) was sorted to taxonomic order and stored separately in ethanol vials. Once pinned and labeled with locality information, all flower flies were given to Andrew Young at the Canadian National Collection of Insects, Arachnids, and Nematodes in Ottawa, Canada, for identification. Prepared and labeled bees were primarily determined by J. Rykken. Significant taxonomic assistance for solitary bees was provided by T. Griswold and H. Ikerd at the USDA ARS Bee Biology and Systematics Lab in Logan, UT, and J. Gibbs at the University of Manitoba; assistance with bumble bees in the subgenus *Alpinobombus* was provided by P. Williams at the Natural History Museum in London, U.K.

Specimen Deposition

All specimens were assigned and labeled with ICMS catalog numbers and an accession number (GAAR-00245). All specimens will be deposited at the University of Alaska Museum (UAM) at the University of Alaska Fairbanks.

Habitat Data

Each sampling site was characterized by habitat type (Table 1). All site-specific habitats were then reclassified into five more general habitat types for summary analysis: (1) disturbed (including roadsides, fields, lawns); (2) lake edge (including both beaches and marshes); (3) riparian (including gravel and sandy bars and bluffs); (4) shrubs/trees (including a cottonwood grove and willow thickets); and (5) tundra (including dry and wet).

Data Analysis

All specimen, sample, and associated data were entered into an Microsoft Access relational database; graphs were created with Microsoft Excel. I used the diversity software EstimateS version 9.1.0 (Colwell 2013) to generate sample-based rarefaction curves for comparing expected numbers of pollinator species collected in different habitats, as sample number increases (shrubs/trees data were excluded in this analysis because there were too few samples). The curves were generated with data from actual collections in four habitats, but I was able to extrapolate curves for less-sampled habitats (disturbed, riparian, lake edge) to match the larger sample size for the most intensively sampled habitat (tundra), using a technique described by Colwell et al. (2012). The slopes of these rarefaction curves also indicate how much more sampling is required to capture the full diversity of each habitat.

Results

Pollinator Diversity and Abundance

In all, we collected 574 bees and 351 flower flies in Gates of the Arctic NPP in 2015 and 2016. These comprised 35 bee taxa and 55 flower fly taxa (some bees and flies were identified only to morphospecies, species group, or genus; Appendix A). Thus, while bees were far more abundant than syrphid flies in our collections, syrphid flies were 1.6 times as diverse as bees (Fig. 2). Four syrphid fly species (*Neoascia meticulosa*, *Parhelophilus laetus*, *Chrysotoxum derivatum*, *Platycheirus chilosia*) and one bee species (*Stelis nitida*) are new published records for Alaska.

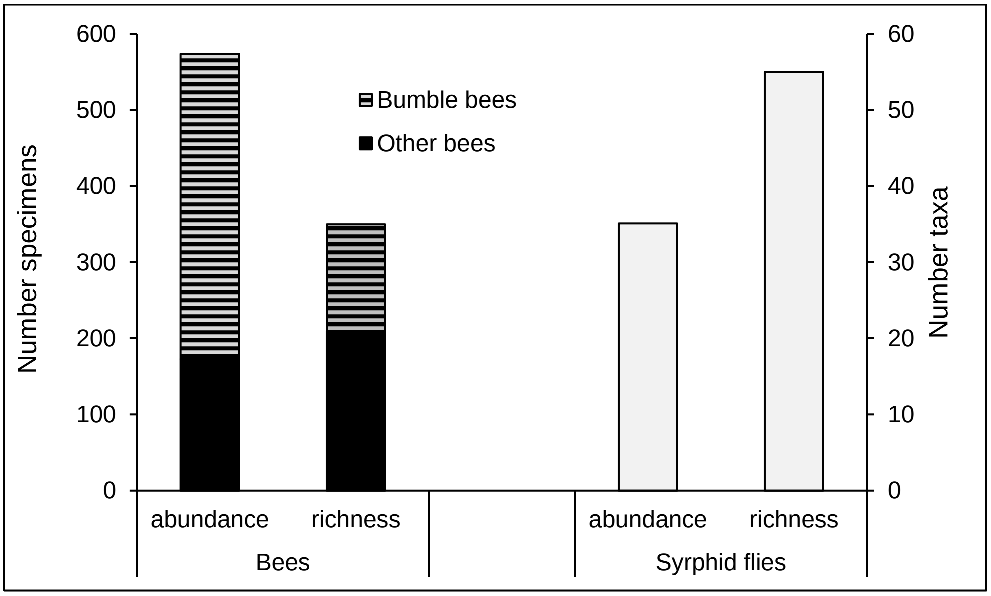

Figure 2. Abundance and taxa richness of bumble bees (*Bombus*), other bees, and flower flies collected in Gates of the Arctic. Note that left axis goes with abundance column and right axis goes with richness column.

Among the bees, five families were represented: Andrenidae, Apidae, Colletidae, Halictidae, and Megachilidae (Appendix A). The most diverse and abundant bee genus by far was *Bombus* (bumble bees), with 14 species and 401 specimens (70% of all the bees; Fig. 3). *Bombus sylvicola* and *B. jonellus* were the most abundant and widespread bumble bee species, making up almost half of the total bumble bees collected. Two rarely collected *Bombus* species are parasites on other bumble bees (*B. bohemicus* and *B. flavidus*). We collected 16 species of solitary bees, and among these, the most abundant were the sweat bee *Lasioglossum tenax* (48 specimens collected at just three sites in Bettles); the cellophane bee, *Colletes impunctatus lacustris* (29 specimens collected at four sites along the Noatak River); the masked bee, *Hylaeus annulatus* (20 specimens collected at nine sites across the park); and the mining bee, *Andrena barbilabris* (15 specimens collected at four sites along the Koyukuk River). We also collected at least three species of cleptoparasites in the genera *Nomada*, *Sphecodes*, and *Stelis*. These species all parasitize solitary bees within their own families except for *Nomada* which primarily parasitize species of *Andrena*. Figure 4 showcases the diversity of various bee taxa collected in the park.

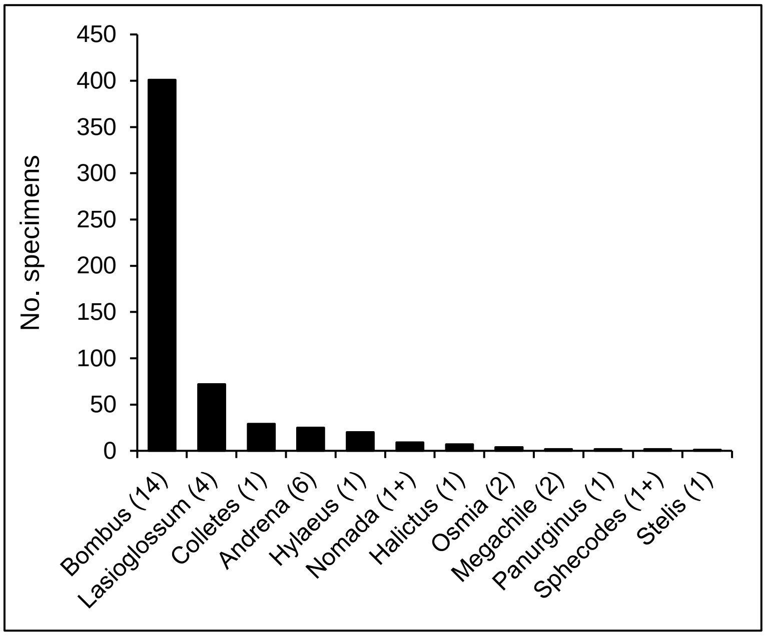

Figure 3. Twelve genera of bees collected in Gates of the Arctic in decreasing order of abundance. Numbers in parentheses represent the species richness for each genus ("+" indicates that multiple specimens were identified to genus only, so more than one species may be represented).

Figure 4. Representative bee species and genera found in Gates of the Arctic. From top left, **Row 1**: *Andrena barbilabris*, *Bombus melanopygus*, *Sphecodes* sp.; **Row 2**: *Nomada* sp., *Megachile* sp., *Bombus occidentalis*; **Row 3**: *Lasioglossum inconditum*, *Bombus perplexus*, *Stelis nitida*; **Row 4**: *Megachile* sp., *Hylaeus* sp., *Bombus bohemicus*. Note that bees in photos are *not* from Gates of the Arctic, and photographs identified only to genus represent different species than those collected in the study. All photographs courtesy of USGS Bee Inventory and Monitoring Lab.

Among the flower flies, the most diverse and abundant subfamily was the Syrphinae with 38 taxa and 232 specimens (or 66% of all flies); all species are predators of aphids. The most diverse genus was *Platycheirus* (11 species; Fig. 5), predominantly an arctic/alpine group, and widespread across the areas we sampled. The most abundant genus was *Syrphus* (Fig. 5), with only four species but also widespread. The most abundant and widespread species included the common flower fly, *Syrphus ribesii* (40 specimens collected at 15 sites across the park) and *Sphaerophoria abbreviata* (35 specimens collected at 22 sites across the park). Together, these two species made up more than one fifth of all the flower flies we collected. Figure 6 showcases the diversity of various bee taxa collected in the park.

Half of the pollinator taxa we collected were represented by three or fewer individuals, and 31% of all documented taxa were collected at a single site.

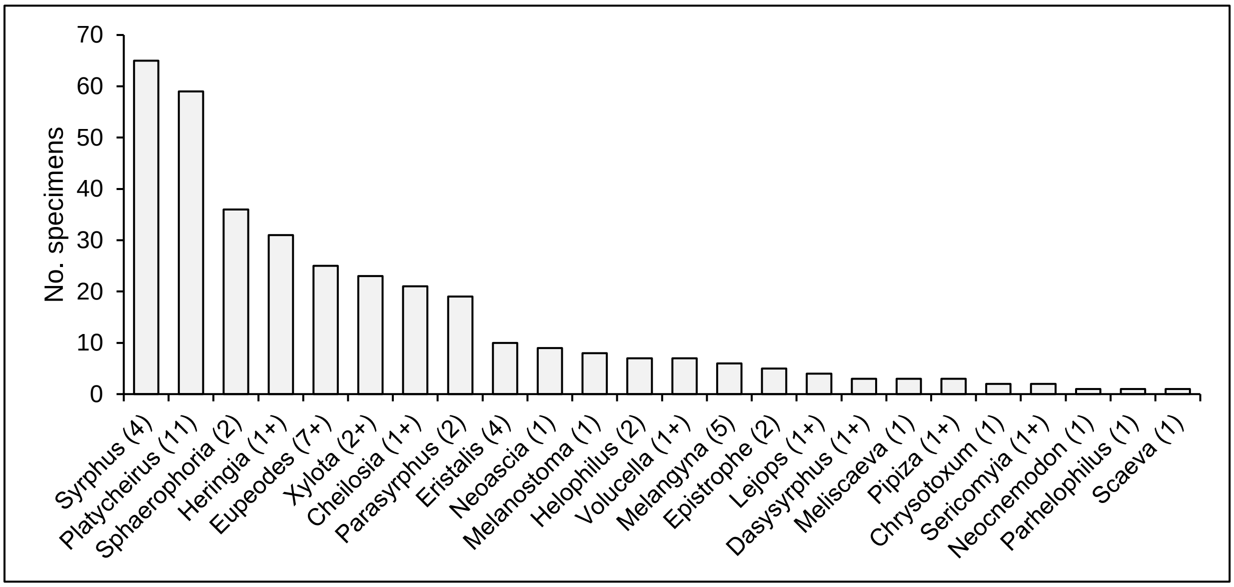

Figure 5. Twenty-four genera of flower flies (Syrphidae) collected in Gates of the Arctic in decreasing order of abundance. Numbers in parentheses represent the species richness for each genus (“+” indicates that multiple specimens were identified to genus only, so more than one species may be represented).

Figure 6. Representative flower fly species and genera (Family Syrphidae) found in Gates of the Arctic. From top left, **Row 1**: *Heringia* sp., *Eristalis flavipes*, *Cheilosia* sp.; **Row 2**: *Epistrophe grossulariae*, *Chrysotoxum* sp., *Sphaerophoria* sp.; **Row 3**: *Platycheirus* sp. head, *Syrphus ribesii*, *Meliscaeva cinctella*; **Row 4**: *Melanostoma mellinum*, *Platycheirus* sp. larva, *Melangyna labiatarum*. Note that flies in photos are *not* from Gates of the Arctic, and photographs identified only to genus represent different species than those collected in the study. All photographs courtesy of Tom Murray (www.pbase.com/tmurray74).

Comparison Between Habitats

In all, we collected a total of 23 bee bowl samples and 65 net samples across 71 sites in 2015 and 2016 (Table 1). Sampling intensity was not equal across habitats (Fig. 7a). Almost one third (31%) of bee bowl samples were collected in disturbed habitats (i.e., in Bettles and Anaktuvuk Pass) versus 17% of net samples, while the proportion of net samples taken in riparian habitats (28%) was far higher than the proportion of bee bowls (17%). The proportion of bee bowl and net samples taken in tundra and lake edge habitats was similar; no bee bowls were deployed in the shrubs/trees habitat.

Overall, the proportion of pollinator specimens collected in each habitat reflected the differences in sampling intensity, although the tundra yielded far fewer specimens and the disturbed habitats yielded many more specimens than sampling intensity alone would predict (Figs. 7a,b). When bees and flower flies were examined separately, their relative proportions in each habitat were quite similar, with the largest difference seen in the riparian habitat, where 34% of all flower flies were collected, but only 27% of all bees.

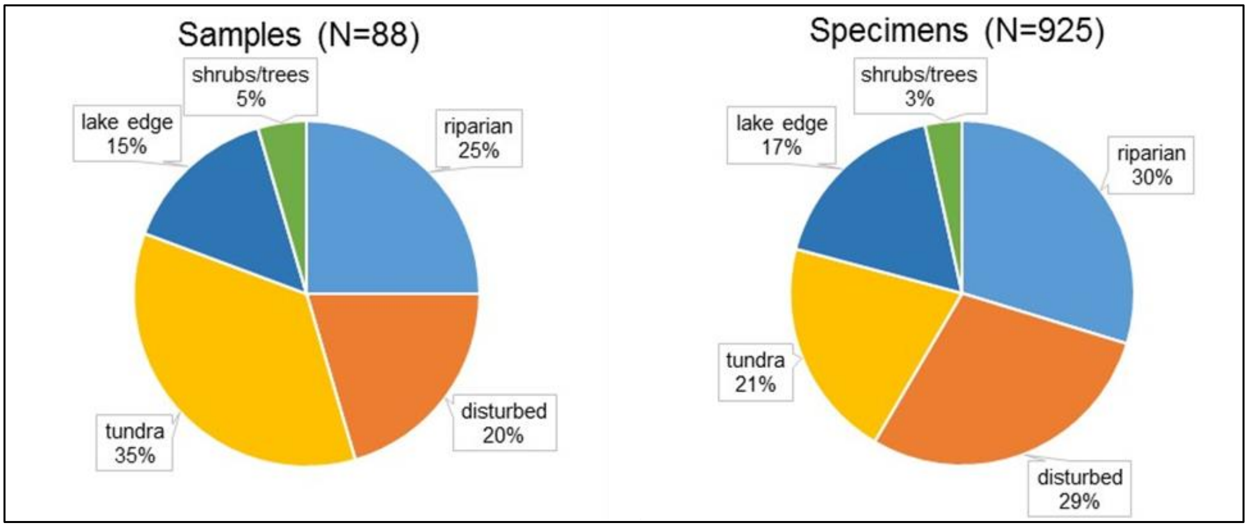

Figure 7. Proportion of **(a)** pollinator samples (23 bee bowl samples + 65 net samples combined) and **(b)** pollinator specimens (574 bees + 351 flower flies) collected in five general habitat types across Gates of the Arctic in 2015 and 2016.

Riparian areas had the most taxa (52) of any habitat, while shrubs/trees had the least (16). Extrapolated rarefaction curves for the four more intensively sampled habitats (i.e., excluding shrubs/trees) indicated that if sample sizes were equal across habitats, then disturbed and riparian habitats would have the most species while tundra habitats would have the least (Fig. 8). The upward trajectories of the rarefaction curves suggest that additional sampling would yield many more species in all habitats.

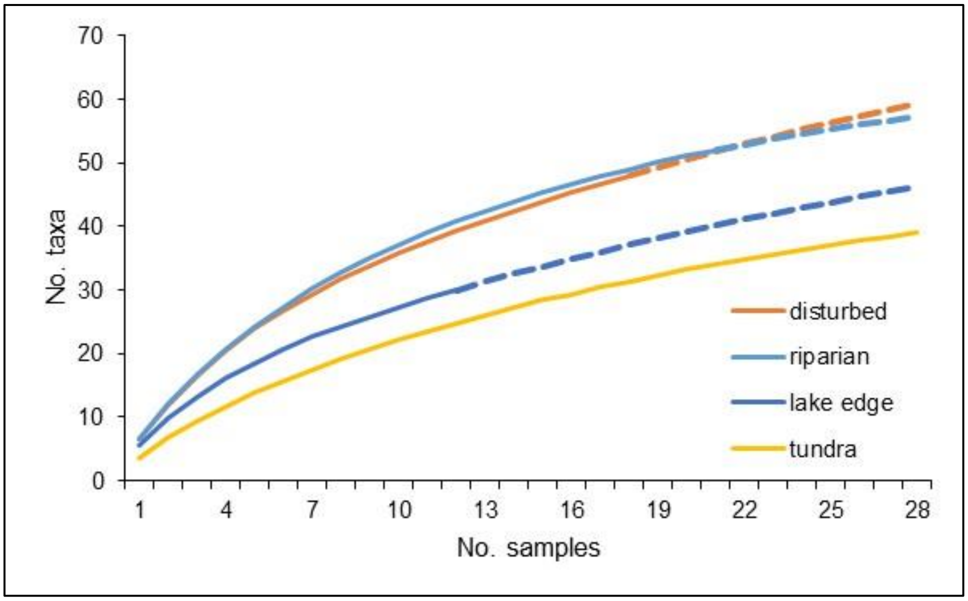

Figure 8. Rarefaction curves for total numbers of pollinator taxa collected in four habitats in Gates of the Arctic. Extrapolated rarefaction values (beyond the number of samples actually collected from a habitat) are indicated by a dashed line (see Methods for explanation).

There were many species that appeared to be habitat generalists, occurring in at least four or five habitat types. These included more than half of the bumble bees (Table 1), the masked bee *Hylaeus annulatus* (but this species was restricted to elevations below 500 m in our study), and the flower flies, *Melanostoma mellinum*, *Platycheirus naso*, *Sphaerophoria abbreviata*, *Syrphus attenuatus*, and *Syrphus ribesii*. Other relatively abundant species (≥ 10 specimens) were collected predominantly in just one habitat, including: the sweat bees *Lasioglossum tenax* and *L. comagenense* in disturbed habitats; the mining bee, *Andrena barbilabris* and the cellophane bee, *Colletes impunctatus lacustris*, in riparian habitats; and the flower fly, *Parasyrphus tarsatus*, in riparian habitats. Several abundant species were collected only at lower elevations (below 500 m): *Andrena barbilabris* (found only in Koyukuk River sites); the bumble bee *Bombus mixtus* (all collected south of the Brooks Range); the masked bee, *Hylaeus annulatus* (all but one specimen from Lake Isiak collected south of the Brooks Range); and both the sweat bees, *Lasioglossum tenax* and *L. comagenense* (almost all collected in Bettles).

Floral associations

Pollinators were net-collected on a variety of plants. While it was not possible to ascertain whether a particular bee or flower fly was resting, foraging on nectar or pollen, or actively pollinating the plant on which it was found, we kept track of "visitation" to plants by a small subset of the pollinators we collected (Table 2). Within our limited dataset, the three most widespread pollinators in the study, *Bombus sylvicola* and *B. jonellus* (bumble bees) and *Sphaerophoria abbreviata* (flower fly), were also found on the highest diversity of plant genera.

Table 2. Pollinators net-collected from various plant genera in Gates of the Arctic. Associations represent "visitations" on flowers, not necessarily pollen-collecting/transferring events. These represent a relatively small subset of net-collected pollinators, we were not able to keep track of host plants for all net-collected individuals. Plants are grouped by taxonomic family: Aster.= Asteraceae; Eric.= Ericaceae; Fab.= Fabaceae; Lil.= Liliaceae; Ona.= Onagraceae; Pol.= Polygonaceae; Por.= Portulacaceae; Ran.= Ranunculaceae; Sal.= Salicaceae; Saxifr.= Saxifragaceae.

		Plants (Family)																	
Taxon	**Pollinator Species**	***Achillea* (Ast)**	***Taraxacum* (Ast)**	***Vaccinium* (Eri)**	***Hedysarum* (Eri)**	***Oxytropis* (Fab)**	***Allium* (Lil)**	***Chamaenerion* (Ona)**	***Polygonum* (Pol)**	***Claytonia* (Por)**	***Aconitum* (Ran)**	***Dryas* (Ros)**	***Potentilla* (Ros)**	***P. palustris* (Ros)**	***Rosa* (Ros)**	***Spiraea* (Ros)**	***Salix* (Sal)**	***Boykinia* (Sax)**	***Saxifraga* (Sax)**
BEES (ANTHOPHILA)	*Andrena barbilabris*	–	x	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–
	Bombus bohemicus	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–
	Bombus cryptarum	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
	Bombus flavidus	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–
	Bombus flavifrons	–	–	–	x	x	–	x	–	–	–	–	–	–	–	–	–	–	–
	Bombus frigidus	–	x	–	x	–	–	x	–	–	–	–	–	x	–	x	–	–	–
	Bombus jonellus	–	x	x	x	–	–	x	–	–	x	x	–	x	–	x	x	–	–
	Bombus kirbiellus	–	–	–	–	–	–	x	–	–	–	–	–		–	–	–	–	–
	Bombus mixtus	–	x	–	–	–	–	–	–	–	–	–	–	x	–	x	–	–	–
	Bombus neoboreus	–	–	–	x	–	–	x	–	–	–	–	–	x	–	–	–	–	–
	Bombus perplexus	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bombus polaris	–	–	–	x	–	–	x	–	–	–	–	–	–	–	–	–	–	–
	Bombus sylvicola	–	x	x	x	–	–	x	x	x	–	x	–	x	–	x	–	–	–
	Halictus rubicundus	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Hylaeus annulatus	–	–	–	–	–	x	–	–	–	–	–	x	–	–	x	–	–	–
	Lasioglossum boreale	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	–	–	–
	Lasioglossum comagenense	–	x	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–
	Lasioglossum inconditum	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–
	Lasioglossum tenax	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Megachile circumcincta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
FlOWER FLIES (SYRPHIDAE)	*Epistrophe grossulariae*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
	Eristalis anthophorina	x	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
	Eristalis hirta	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 2 (continued). Pollinators net-collected from various plant genera in Gates of the Arctic. Associations represent “visitations” on flowers, not necessarily pollen-collecting/transferring events. These represent a relatively small subset of net-collected pollinators, we were not able to keep track of host plants for all net-collected individuals. Plants are grouped by taxonomic family: Aster.= Asteraceae; Eric.= Ericaceae; Fab.= Fabaceae; Lil.= Liliaceae; Ona.= Onagraceae; Pol.= Polygonaceae; Por.= Portulacaceae; Ran.= Ranunculaceae; Sal.= Salicaceae; Saxifr.= Saxifragaceae.

Taxon	Pollinator Species	Plants (Family)																	
		Achillea **(Ast)**	***Taraxacum*** **(Ast)**	***Vaccinium*** **(Eri)**	***Hedysarum*** **(Eri)**	***Oxytropis*** **(Fab)**	***Allium*** **(Lil)**	***Chamaenerion*** **(Ona)**	***Polygonum*** **(Pol)**	***Claytonia*** **(Por)**	***Aconitum*** **(Ran)**	***Dryas*** **(Ros)**	***Potentilla*** **(Ros)**	***P. palustris*** **(Ros)**	***Rosa*** **(Ros)**	***Spiraea*** **(Ros)**	***Salix*** **(Sal)**	***Boykinia*** **(Sax)**	***Saxifraga*** **(Sax)**
FLOWER FLIES (SYRPHIDAE) continued	*Eristalis obscura*	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Eupeodes lapponicus	–	–	–	–	–	–	x		x	–	–	–	–	–	x	–	–	–
	Eupeodes luniger	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Melangyna arctica	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
	Melangyna labiatarum	x	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
	Melanostoma mellinum	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	x
	Meliscaeva cinctella	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
	Neeoascia meticulosa	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–
	Parasyrphus tarsatus	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	x	–
	Platycheirus amplus	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–
	Platycheirus granditarsis	–	–	–	–	–	–	–	–	–	–	–	–	x		–	–	–	–
	Platycheirus podagratus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
	Sphaerophoria abbreviata	x	–	–	–	–	–	–	–	–	–	x	x	–	–	x	x	–	x
	Syrphus attenuatus	x	x	–	–	–	–	–	–	–	–	x	–	–	x	–	–	–	–
	Syrphus ribesii	x	x	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–
	Syrphus vitripennis	x		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Discussion

Pollinator Distribution and Diversity

Despite the limited geographic scope and duration of our surveys, this preliminary investigation into bee and flower fly diversity across Gates of the Arctic provided us with a wealth of information on several very important groups of arctic pollinators. Not surprisingly, many of the species we collected have primarily arctic or arctic/alpine distributions. Seventy-three percent of the flower flies and almost half of the bees we identified to species are Holarctic, meaning they also occur in Europe and northern Asia. Some of these Holarctic species are restricted to circumpolar/boreal ranges at high latitudes, including the aptly named bumble bee, *Bombus polaris*. Other species have much more cosmopolitan ranges, including the flower fly, *Melanostoma mellinum*, which ranges as far south as the Mediterranean and North Africa in the Old World.

Within the park, species distributions also ranged from widespread to localized. The more commonly collected species such as the bumble bees *Bombus sylvicola* and *B. jonellus*, and the flower flies *Sryphus ribesii* and *Sphaerophoria abbreviata* were collected across all elevations and regions of the park. Other taxa were restricted to areas higher in elevation or further north in the park (within or north of the Brooks Range), such as all of the bumble bees in the subgenus *Alpinobombus* (*B. kirbiellus*, *B*. neoboreus, *B. polaris*) or the flower fly *Parasyrphus tarsatus.* Likewise, many taxa were restricted to lower elevations or areas to the south of the park within the boreal forest landscape, including many of the solitary bees. Armbruster and Guinn (1989) note that Alaska solitary bees are most abundant and diverse in "open, sunny habitats at low elevations," especially on south-facing slopes and in early successional habitats such as floodplains and roads, but *not* in alpine areas. Because of their small body mass and lack of insulation, they must be able to bask in full sun either on the ground or in flowers, and they cannot tolerate the extreme thermal regimes that bumble bees do at higher elevations and in more shaded areas (Bishop and Armbruster 1999). It is also interesting to note that several of the solitary species were collected in a single drainage, including the mining bee *Andrena barbilabris* at several sites along the Koyukuk (and Middle Fork) River, and the cellophane bee, *Colletes impunctatus lacustris*, at several sites along the Noatak River. This is likely an artifact of under-sampling across this vast park, but would be interesting to investigate in future survey work.

Focal Pollinator Taxa

Bumble Bees (*Bombus* Species)

As expected, bumble bees made up the majority (70%) of the bees in the survey. Bumble bees are well-adapted to the adverse climates of high latitudes and altitudes because of their comparatively large body size, long, dense pelage, and ability to warm their thoracic muscles through "shivering" which allows them to fly at lower temperatures than most insects (Kearns and Thomson 2001). Bumble bees are typically generalist foragers with relatively long tongues and these traits are also beneficial in arctic systems where the flowering season is compressed. Only the newly-mated queens from bumble bee colonies overwinter, the rest of the colony (the founding queen, workers, males) perish at the end of the growing season.

In addition to social bumble bees, I documented two species of social parasites, *Bombus bohemicus* and *B. flavidus*. These bees do not build nests of their own, nor do they have a worker caste. Instead, a female bee will invade the nest of a host (social) species, kill the queen, and usurp the nest, so that host workers will raise her young. Thus, the female bees do not collect pollen and nectar for the nest, and have no special structures on their legs (corbiculae) for pollen transport. Likely hosts for *Bombus bohemicus* in Alaska include *B. occidentalis* and *B. cryptarum*; suspected hosts for *B. flavidus* include *B. occidentalis* and species in the subgenus *Pyrobombus* (Williams et al. 2014).

Solitary and Cuckoo Bees

Although bumble bees dominated many of the habitats in our study, thirty percent of the bees we collected were solitary bees and parasitic "cuckoo" bees, found across all habitats except shrubs/trees. These comprised bees in five families, including soil-nesting mining bees (e.g., *Andrena*, *Panurginus*, *Halictus, Lasioglossum, Colletes*), stem and twig-nesting masked bees (*Hylaeus*), leafcutter bees (*Megachile*), mason bees (*Osmia*), and several genera of cuckoo or cleptoparasitic bees (*Nomada*, *Sphecodes, Stelis*).

Most of these bees are solitary nesters, with each female building and provisioning her own nest, although some species nest in aggregations. The two sweat bee genera, *Halictus* and *Lasioglossum* include species that are solitary nesters at northern latitudes but are social further south, with a division of labor among generations. The cuckoo bees, also called cleptoparasites, lay their eggs in the nest of a host solitary bee. Typically, a parasite's host is from a genus within the same family, however, the majority of *Nomada* cuckoo bees (Family Apidae) are parasites of mining bees in the genus *Andrena* (Family Andrenidae). After the egg is deposited in an individual nest cell, the developing cuckoo larva kills the host egg or larva and eats their nectar and pollen provisions. The cuckoo lifestyle is not uncommon among bees, a summary of surveys conducted in various regions of the U.S. suggests that parasitic bees make up between 10 and 25% of bee communities (Wcislo 1987). Because their success depends on healthy populations of host bees, parasitic bees (including parasitic bumble bees) can serve as good indicators of the overall health of bee communities for pollinator monitoring programs (Sheffield et al. 2013).

Flower Flies (Syrphidae)

Syrphid flies made up only 38% of the total pollinator catch, but 61% of the taxon diversity. Generic diversity for syrphid flies was twice that for bees. We collected syrphid flies in three subfamilies: Syrphinae, Pipizinae, and Eristalinae. Adults of all subfamilies visit flowers to feed on pollen and/or nectar, and thus effect pollination. Their mobile larvae, however, lead very different lives. Larval Syrphinae and Pipizinae are predators, feeding mainly on aphids and other soft-bodied homopterans that live on various parts of plants, shrubs, and trees. Some Syrphinae have been used for biocontrol of aphid pests in agriculture. Larval Eristalinae are more varied in their habits. *Cheilosia* larvae feed on fungi or plant tissue, while the larvae of many other genera (e.g., *Eristalis*, *Helophilus*, *Sericomyia*) feed on decaying organic matter in stagnant, organic water (Vockeroth and Thompson 1987). *Volucella* larvae are unique in living in the nests of social wasps and bees (including bumble bees), where they scavenge on debris and dead larvae. *Xylota* larvae are usually associated with trees, feeding on decaying wood or sap.

As adults, flower flies are quite conspicuous while feeding on flowers, and their mimicry of stinging bees and wasps is believed to be a defensive strategy against predators (Vockeroth and Thompson 1987). Among the flower flies collected in Gates of the Arctic, the most convincing bumble bee mimics are *Volucella* species and *Eristalis flavipes*, all large-bodied flies with relatively thick piles of yellow, orange, and/or black pile on their thorax and abdomen. Adults of the much sleeker and closely related genera *Platycheirus* and *Melanostoma* are unique in that they feed on the pollen of wind-pollinated plants such as grasses.

Species of Interest or Concern

Bombus bohemicus is a social parasite of other bumble bees; it ranges from northeastern North America south into the Appalachian Mountains, and northwest through Canada to Alaska. It also occurs in Europe and Asia. This species appears to be in decline throughout much of its range, and in the eastern/midwestern U.S. this may be attributed to a decline in known host populations, including *B. affinis* (now listed as endangered under the Endangered Species Act) and *B. terricola* (also observed to be in decline).

Bombus occidentalis is another bumble bee species known to be in dramatic decline in other parts of its range (Washington, Oregon, and northern California; Evans et al. 2008, Cameron et al. 2011) . This species was extremely common on the west coast of the U.S. until the mid-1990's, after which sightings dropped precipitously, despite intensive surveys (Evans et al. 2008). It was initially suspected that the primary cause for its decline was infection by a microsporidian fungus, *Nosema bombi*. In the late 1990's, *B. occidentalis* queens were sent to Europe for commercial rearing, and it was thought they picked up exotic strains of the pathogen there, from a related European bumble bee (Evans et al. 2008). Upon return to the U.S., the exotic pathogens from the cultured bumble bees working in greenhouses, were presumed to have "spilled over" into surrounding wild bee populations from shared use of flowers (Colla et al. 2006). However, more recent work on the global genetic variation of *N. bombi* suggests that the *Nosema* strain found in declining U.S. bumble bees is not of exotic origin (Cameron et al. 2016). *Bombus occidentalis* appears to be thriving in Alaska with relatively high *N. bombi* infection rates (Koch and Strange 2012, Pampell et al. 2015).

Bombus neoboreus is a member of the subgenus, *Alpinobombus*, which includes several species that have far northern and/or high elevation distributions. *B. neoboreus* is a Nearctic species that ranges from AK north to the Northwest Territories and east to Baffin Island in Nunavut (Williams et al. 2014). Recently, Williams et al. (2016) determined through DNA analysis that "*Bombus neoboreus*" specimens from the St. Elias Mountains in the Yukon and from Denali National Park actually represented a new, albeit morphologically cryptic, species, *B. kluanensis*. Knowing this, I sent all specimens of *B. neoboreus* collected in Gates of the Arctic to P. Williams at the Natural History Museum in London, U.K., for examination and/or molecular analysis. All of the Gates of the Arctic specimens remain valid as *B. neoboreus*.

Bombus kirbiellus is also in the subgenus *Alpinobombus*, and a sister species of *B. balteatus*. The latter name has been used for specimens collected in North America, but Williams et al. (2015) recently suggested, based on genetic evidence, that all New World bees in the group (with the possible exception of specimens from California), are *B. kirbiellus*, while Old World bees in the group are *B. balteatus*. Thus, we are following Williams et al. 2015 for species determinations.

Syrphus sexmaculata and ***Platycheirus nigrofemoratus*** are two species of flower flies in the subfamily Syrphinae that are relatively rare/uncommon (Andrew Young, pers. comm.). Both are Holarctic far northern species.

Pollinator "Bycatch" from Bee Bowls

Although not included among the focal pollinator taxa of our survey in Gates of the Arctic, we saved all butterflies collected in bee bowls (Table 3). One hundred butterflies and skippers were collected from eight different sites, representing 15 species (one species pair, *Erebia youngi*/*E. lafontanei*, could not be separated without dissecting genitalia; and one species determination, *Erebia* ?*occulta*, remained uncertain). Sites included Lake Isiak, Chandler Lake, Walker Lake, Takahula Lake, and the Itkillik River/Oolah Lake. Typically, moths and butterflies are removed (i.e., thrown out) from bee bowl contents because their colored wing scales rub off and attach themselves to fuzzy bees and flies, thus contaminating the specimens of primary interest. Also, most lepidopterists have little interest in examining wet specimens that are missing many of their scales and are difficult to prepare. However, we were fortunate to have the assistance of two enthusiastic lepidopterists (Maxim Larrivée from the Insectarium de Montréal in Canada and Kathryn Daly, a graduate student in the lab of D. Sikes at the University of Alaska Museum) who agreed to look over our bycatch. Their efforts yielded very worthwhile results, including one species rarely observed in Alaska, *Oeneis uhleri* (Uhler's Arctic). Within Alaska, this Nearctic species was only known previously from the Arctic National Wildlife Refuge, where it was collected in 1973. *Oeneis uhleri* has been collected in the Yukon more recently, but not in Alaska. In Gates of the Arctic, we found it near Lake Isiak.

Table 3. List of butterfly and skipper species collected in Gates of the Arctic in 2015 and 2016.

Family	Species	Common name	Total #	Sites (see Table 1)
Hesperiidae	*Hesperia comma (*Linnaeus)	Common branded skipper	7	44,45
Nymphalidae	*Boloria chariclea* (Schneider)	Arctic fritillary	7	22,67,71
	Boloria eunomia (Esper)	Bog fritillary	1	44
	Coenonympha tullia kodiak W.H. Edwards	Common ringlet	2	45
	Erebia ?occulta Roos & Kimmich	Eskimo alpine	3	44
	Erebia youngi Holland/*Erebia lafontainei* Troubridge & Philip	Four-dotted alpine/ Lafontaine's alpine	27	44,45
	Oeneis bore (Esper)	White-veined Arctic	5	44,45
	Oeneis philipi Troubridge	Philip's Arctic	1	45
	Oeneis polixenes (Reakirt)	Polixenes Arctic	1	45
	Oeneis uhleri Gibson	Uhler's Arctic	1	45
Pieridae	*Colias gigantea* Strecker	Giant sulphur	9	44,67,71
	Colias hecla Lefèbvre	Hecla sulphur	12	57,59,67,71
	Colias nastes (Boisduval)	Arctic green sulphur	3	44,67
	Colias palaeno (Linnaeus)	Palaeno sulphur	20	22,24,44,45,57
	Colias philodice Godart	Clouded sulphur	1	44

Habitat and floral associations

Habitat needs for bees and flower flies include: host plants with nectar and pollen for adults (and bee larvae) to feed upon; various other food resources for flower fly larvae (e.g., aphids, plants stems, wood, fungus, decaying organic matter); and nesting substrate for bees (e.g., bare ground or sandy banks, twigs, abandoned insect holes or rodent nests).

Almost all of the pollinator species (bees and flower flies) documented in this survey are considered generalist foragers as adults. A few known exceptions include the mason bee, *Osmia nigriventris*, which is known to favor *Vaccinium* (Rightmyer et al. 2010); and the flower fly, *Platycheirus granditarsis*, which feeds on the pollen of wind-pollinated plants such as *Salix*, Poaceae, and Cyperaceae (Young et al. 2016). Tongue or proboscis length and body size determines which flowers bees and flies can access for nectar and/or pollen; longer tongues are typically able to access deeper or more complex corollas (Gilbert 1981, Armbruster and Guinn 1989). Thus, shorter tongued species (including most flower flies) favor Asteraceae and other open flowers like *Potentilla* or *Rosa*, while long-tongued bumble bees and others are often observed on deeper flowers such as *Mertensia* or *Hedysarum*. Our host plant data were limited, but it appeared that open flowers (e.g., many of the Rosaceae species and *Taraxacum*) attracted both bees and flower flies, while we collected only bumble bees from deeper corolla flowers such as *Hedysarum* and *Vaccinium*. Only flower flies were recorded off the tiny flowers of *Achillea*. Some predaceous larval Syrphinae are associated with host plants, as they specialize on aphids which feed on particular plants (e.g., *Melangyna umbellatarum* larvae feed on umbellifer-feeding aphids; Speight 2011).

Given that the majority of species we collected are known to be generalist foragers, it was remarkable how patchy their presence could be across the landscape. We might walk for an hour across the tundra with many flowers in bloom and see hardly an insect, then come across one small patch of different flowers crowded with pollinators. One case that was particularly dramatic was at the Itkillik river, where river beauty (*Chamaenerion latifolium*) was in dense full bloom on the gravel bars but yielded approximately one bumble bee every five minutes; while on the nearby tundra, there was an abundance of bees on very sparse, tired-looking *Hedysarum*. Similarly at Takahula Lake, pollinators were extremely sparse all along the lake shore, but a small patch of one wetland plant, *Potentilla palustris,* yielded half the pollinators collected during an entire afternoon.

Nesting sites are a critical habitat component for bees. Bumble bees generally nest in abandoned rodent or other nests below ground, or on the ground surface. After emergence from hibernation, the queen searches for a suitable nest in a dry, sunny location, often on south-facing slopes (Kearns and Thomson 2001). Solitary bees in the genera *Andrena*, *Panurginus*, *Colletes*, and *Lasioglossum* typically excavate nests underground, and depend on relatively bare patches of well-drained soil for these nests. Thus it is no surprise that almost all of the solitary ground-nesting bees were collected on the lawns and fields in Bettles; on sandy beaches, banks, and bluffs associated with the Noatak and Koyukuk Rivers; and on the sandy shores of Walker Lake. *Hylaeus* bees are generally twig nesters, and excavate the pithy stems of berry canes or shrubs; they were collected in a wide variety of habitats across the park. Mason bees in the genus *Osmia* typically make use of existing holes in wood (often made by other insects like beetles). We found both species of *Osmia* at just one site on a dry ridge above Walker Lake in tundra with scattered spruce, aspen, and dwarf birch.

Unlike bees, flower flies do not build nests and provision their young, however, their larvae are active foragers and so larval food requirements (e.g., aphids, plants stems, decaying organic matter) are also important habitat components. For example, we collected all specimens of the eristaline flower fly, *Helophilus lapponicus*, near stagnant organic pools of water in the tundra near Lake Isiak. These flies have aquatic larvae with long breathing tubes that allow them to take in air from above water surface. Other eristaline species with similar aquatic larval habits were collected around Bettles and Takahula Lake. Larvae of the genus *Xylota* feed on decaying wood or sap, and we found them exclusively in sites south of the Brooks Range near boreal forest.

Another seldom-documented association of pollinators with aphids was observed in 2016 by a technician working with Fleur Nicklen, botanist with the Central Alaska Network Inventory and Monitoring Program. He observed individuals of *Bombus jonellus* visiting aphids on birch (*Betula*), presumably to forage on the honeydew the aphids secrete. Several additional bumble bee species were foraging on flowers nearby and ignoring the aphids. This behavior is known for honey bees, but until recently there have been few published records of any other bees foraging on this nectar alternative. Bishop (1994) similarly reported *Bombus hypnorum* feeding on aphid honeydew on stone pine (*Pinus pumila*) in the Russian Far East, while other species foraged on nearby flowers. Interestingly, in this case, *B. jonellus* was one of the species avoiding the honeydew. In the eastern U.S., *Bombus terricola* (as well as solitary bees and flower flies) were observed to feed on honeydew that had crystallized on the twigs of stunted balsam firs (*Abies* *balsamifera*) growing in alpine tundra (Batra 1993). The pollinators were also seen licking honeydew off *Vaccinium* leaves growing near the fir. In 2016 in Gates of the Arctic, we also observed *Bombus jonellus* preoccupied on *Salix* (willow) twigs and leaves several times, although did not make the connection with aphids and honeydew. This strategy for using an alternative source for nectar by bees, especially during times when floral abundance is low (e.g., unusually dry periods or early in the season) has recently been suggested as being more common than previously thought (Meiners 2016). It may also be an advantageous strategy as climate change impacts the phenology of host plant-pollinator interactions.

The Relative Importance of Insect Pollinators in Arctic Landscapes

The dependence of plants on insects for pollination in arctic systems has been a topic of research and discussion among entomologists and botanists alike (Mosquin and Martin 1967, Hocking 1968, Kevan 1972). While plants have evolved many strategies for successful reproduction, including asexual reproduction, self-pollination, and wind pollination, insects are undoubtedly critical for the survival of many plant species in arctic and subarctic landscapes (Kevan 1972).

The relative contribution of different insect taxa to plant pollination also varies with latitude and altitude (Elberling and Olesen 1999). Among the focal taxa in this survey, bumble bees were noticeably more conspicuous and widespread than most solitary bees or flower flies. As generalist foragers with strong thermoregulatory capabilities, *Bombus* are ideally suited to foraging in more severe climates, and thus have an important role in alpine and subarctic pollination. Their densely hairy bodies are also very effective at transferring pollen between plants. Though extremely diverse in more temperate climates, solitary bees, which often have more specialized associations with host plants, are also more limited by their thermal capacities in extreme climates (Armbruster and Guinn 1989, Bishop and Armbruster 1999). The contribution of flower flies as pollinators has received less attention than bees, but Bischoff et al. (2013) compared pollinator performance on two alpine herbs and found that a solitary masked bee delivered 3 to 10 times as much pollen to receptive stigmas as did a flower fly, though the two taxa made similar numbers of visits to the plants. Thus, per-visit effectiveness is important to consider in addition to visitation rate when comparing pollinator contributions. Flower fly species also likely vary in their pollen transfer effectiveness, with hairy eristaline species (e.g., *Bombus* mimics such as *Eristalis flavipes*) probably carrying more pollen than relatively smooth flies.

Casual observations during our pollinator surveys suggested that a diversity of flies were more abundant than either bees or flower flies on many flowers. The domination of Diptera on arctic and alpine flowers is well-documented (Mosquin and Martin 1967, Kevan 1972, Elberling and Olesen 1999). Flower flies make up a small proportion, but other fly taxa which are known to visit flowers in abundance include: Anthomyiidae (root maggot flies), Muscidae (house flies and relatives), Calliphoridae (blow flies), Sciaridae (dark-winged fungus gnats), Chironomidae (non-biting midges), Phoridae (scuttle flies), and Empididae (dance flies; Elberling and Olesen 1999). Tiusanen et al. (2016), studying insect visitors to *Dryas* in northeast Greenland, found that the abundance of muscid flies (generally large, hairy abundant flies that actively visit flowers) was a key predictor for seed set in *Dryas*, while overall insect abundance or species richness (including bees and flower flies) had little effect on seed set in their study. Levesque and Burger (1982) working in an eastern North American alpine habitat, found that even though bumble bees carried an average of 13 times more pollen than many of the flies, muscid and anthomyiid flies in particular were active on cold, cloudy days when bumble bees and flower flies were not observed on flowers. In our Gates of the Arctic survey, significant numbers of non-flower flies comprised "bycatch" in bee bowls. These specimens are currently stored in ethanol at the UAM, and are accessible for future study. Unfortunately, the taxonomy of these other dipteran groups can be extremely challenging.

Educating Park Staff and Visitors About Pollinators

An important goal of the survey was to foster awareness and appreciation of insect pollinator diversity, natural history, and threats to park staff and visitors. Gates of the Arctic boasts an impressive diversity of vertebrate fauna which visitors come to view and learn about, but, as in most national parks, the far vaster diversity of the park's "microwilderness" has thus far received little attention (Rykken and Farrell 2013). In large part, this is because the tiny size of its denizens makes them difficult to view, and also because accessible information is scarce.

The remote nature of the park makes opportunities for direct outreach to staff and visitors challenging. Ranger stations at Bettles, Coldfoot, and Anaktuvuk Pass are obvious places to disseminate information. I gave one presentation on pollinators to a mixed audience of park staff, local residents, and park visitors at the Bettles Visitor Center in 2015. The ranger station at Anaktuvuk Pass receives far fewer visitors, but we plan to make a pollinator display (pinned specimens and accompanying information) for the visitor resource room. The ranger who is stationed at Anaktuvuk Pass (Al Smith) has accompanied me on most of my collecting trips, thus has also learned a great deal about native pollinators.

Another way to reach visitors and other general public is through the Gates of the Arctic website. With the help of a GIS intern in Fairbanks, we are working towards creating a story map that will show off pollinator diversity across our sampling sites and also provide natural history information. Other existing online resources that could be linked to a pollinator-themed page on the park website include a virtual tour of Denali pollinators (https://www.nps.gov/rlc/murie/virtual-tours.htm) which covers many of the same species as are found in Gates of the Arctic, and Bee Observer Cards (available through the Encyclopedia of Life http://eol.org/info/498), a tool that encourages visitors to observe and learn about native bees in Gates of the Arctic as well as in their own neighborhoods.

Threats to Pollinators and the Need for Monitoring

Insect pollinators are intimately linked to their host plants in complex ecological networks, and thus they may serve as effective indicators of ecosystem integrity. One of the most urgent threats facing arctic ecosystems in protected areas is climate change. Species in environments with compressed growing seasons and extreme climates have evolved a variety of complementary physiological adaptations and behaviors to survive such conditions, and thus responses to changes in temperature and moisture may be complex and difficult to predict (Danks 2004). One danger is that host plants and their pollinators will respond to climate change at different rates, so that the timing of flowering will no longer coincide with pollinator emergence, particularly detrimental in climates with shorter growing seasons, or for species with a narrower range of host plants (Bartomeus et al. 2011, Iler et al. 2013, Gillespie et al. 2016).

Climate change may also drive shifts in geographical ranges of pollinators, especially northwards in latitude or upwards in elevation. There is a growing body of research looking at effects of climate change on pollinator distribution and diversity in arctic and alpine systems (e.g., Dirnböck et al. 2011, Franzén and Öckinger 2012). For example, Kerr et al. (2015) showed that southern range limits for many northern bumble bee species in Europe and North America have shifted northwards while their northern range limits have remained static (thus compressing the overall range), and southern species have moved upward in elevation over the last century. One of the common conclusions and recommendations of these alpine and northern studies is that structured survey and monitoring on both local and global scales is imperative.

Bumble bee declines, in particular, have received significant attention worldwide (Kosior et al. 2007, Goulson et al. 2008, Cameron et al. 2011). Williams et al. (2009) compared an assortment of species characteristics (e.g., body size, competition, food specialization) across bumble bee faunas on three continents to determine which traits correlated most strongly with a species' susceptibility to decline. They concluded that bees at highest risk include species that are climate specialists and species that live close to the edge of their climatic range. Among Gates of the Arctic bumble bees, we might expect that the species most susceptible to decline in the face of a changing climate would be those restricted to alpine/arctic or circumpolar regions, such as species in the subgenus *Alpinobombus*: *Bombus kirbiellus, B. neoboreus,* and *B. polaris*. Other Gates of the Arctic pollinators with primarily northern or alpine distributions are also good candidates for monitoring, including bees such as the small sweat bee *Lasioglossum boreale* and the cellophane bee, *Colletes impunctatus lacustri*s as well as flower flies such as *Eupeodes curtus*, *Parasyrphus tarsatus*, *Syrphus sexmaculata*, *Platycheirus nigrofemoratus,* and *Platycheirus chilosia* (which we documented in Alaska for the first time).

Although we did not have an explicit objective to set up a pollinator monitoring program for the park, this preliminary survey work does serve to establish a baseline database of pollinator diversity and distribution across various habitats and landscapes in Gates of the Arctic. It will be important to build on this database, there are undoubtedly many more species to discover, and gathering more distribution data for known species will also be essential in order to document any species declines in the future. Beyond park boundaries, these pollinator surveys will also provide valuable information (including new species records) for the Alaska arthropod database (arctos.database.museum) and for global biodiversity databases (e.g., www.discoverlife.org).

Conclusions and Recommendations

This preliminary survey of Gates of the Arctic pollinators, although constrained by time and spatial coverage, establishes a baseline database for the diversity and distribution of two key pollinator groups, bees and flower flies. The fauna documented in the park thus far suggests that a diversity of bumble bees are key pollinators in all sampled habitats, foraging on a variety of plant hosts, but some species (especially in the subgenus *Alpinobombus*) occur primarily at higher elevations and latitudes in the tundra of the Brooks Range. Most (but not all) solitary bee species were found southwards and at lower elevations within boreal forest landscapes. There are certainly many more solitary species to be discovered, especially in sandy habitats associated with rivers, lakes, and other wetlands. Flower flies were far more diverse than bees, and collectively occurred at a broad range of elevations and latitudes.

Clearly, there is still much work to be done in Gates of the Arctic in order to gain a more comprehensive understanding of the current pollinator fauna, and also to prepare for monitoring changes in diversity, species composition, abundance, phenology, and range shifts over time.

Future priorities should include:

1. Conduct additional basic survey work of bees, flower flies, and also butterflies, targeting more of the large drainages in the Brooks Range, including sandy river banks which provide good nesting habitat for solitary bees. Also focus on collecting more host plant data, especially for solitary bee species.

2. Keep a look out for rare pollinator species, such as the butterfly *Oeneis uhleri*, currently known only from Isiak Lake in the park, and the newly described bumble bee, *Bombus kluanensis*, currently known only from Denali NPP in Alaska.

3. Begin an exploration of other dominant pollinators in the park, especially the non-syrphid flies (e.g. calypterates). As a start, facilitate the identification of the very abundant collections of bee bowl "bycatch" flies now stored in ethanol at UAM if taxonomists can be found.

4. Consider a long-term future pollinator monitoring program, especially for species that currently have clear range preferences south of the Brooks Range (e.g., some of the solitary bees or syrphids in the genera *Xylota* and *Heringia*) versus more northern tundra species such as the bumble bees *Bombus kirbiellus*, *B. neoboreus*, *B. polaris* and flower flies such as *Parasyrphus tarsatus*.

5. Continue to educate park staff and visitors about Gates of the Arctic pollinators. Educational materials could include: a display case of bee and flower fly specimens and/or a poster of conspicuous pollinators in the visitor centers in Bettles, Anaktuvuk Pass, or Coldfoot; a field guide to common bumble bees (and mimics) in the park also available at visitor centers; a pollinator page on the park website with a story map and/or links to other regional source of information (e.g., the Denali virtual tour of pollinators).

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Appendix A. List of Bee and Flower Fly Taxa Collected in Gates of the Arctic NPP in 2015-2016.

Table A-1. Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Diptera Family: Syphidae Subfamily: Eristalinae	*Cheilosia* sp.		Pollen fly	21	13	185-756	5	1	12	1	2	NA	plants/fungi	–
	Eristalis anthophorina	(Fallén)	Orange-spotted drone fly	3	2	235-242	1	2	–	–	–	NA	decay. org./water	Holarctic
	Eristalis flavipes	Walker	Orange-legged drone fly	1	1	236	–	1	–	–	–	NA	decay. org./water	Nearctic
	Eristalis hirta	Loew	Hirsute drone fly	3	2	208-242	3	–	–	–	–	NA	decay. org./water	Holarctic
	Eristalis obscura	Loew	Dusky drone fly	3	3	185-242	3	–	–	–	–	NA	decay. org./water	Holarctic
	Helophilus hybridus	Loew	Wooly-tailed sun fly	1	1	188	1	–	–	–	–	NA	decay. org./water	Holarctic
	Helophilus lapponicus	Wahlberg	Yellow-margined sun fly	6	2	481-522	–	–	–	–	6	NA	decay. org./water	Holarctic
	Lejops sp.		Swamp fly	4	4	203-235	1	3	–	–		NA	decay. org./water	–
	*Neoascia meticulosa**	(Scopoli)	Fen fly	9	2	214-250	–	8	–	–	1	NA	decay. org./water	Holarctic

* New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Diptera Family: Syphidae Subfamily: Eristalinae (continued)	*Parhelophilus laetus**	(Loew)	Common bog fly	1	1	236	–	1	–	–	–	NA	decay. org./water	Nearctic
	Sericomyia arctica/jakutica	–	Pond fly (Arctic/Northern)	2	2	203-214	1	1	–	–	–	NA	decay. org./water	Holarctic
	Volucella sp.	–	Swiftwing	7	6	467-921	–	–	3		4	NA	scavenger	–
	Xylota sp.	–	Forest fly	3	2	203-214	1	2	–	–	–	NA	decay. wood	–
	Xylota subfasciata	Loew	Hairy-horned forest fly	20	4	179-224	6	13	1	–	–	NA	decay. wood	Nearctic
Order: Diptera Family: Syphidae Subfamily: Pipizinae	*Heringia* sp.	–	Smoothleg	31	9	179-340	9	1	21	–	–	NA	aphid predator	–
	Neocnemodon sp.	–	Spikeleg	1	1	188	1	–	–	–	–	NA	aphid predator	–
	Pipiza sp.	–	–	3	3	194-340	–	–	3	–	–	NA	aphid predator	–
Order: Diptera Family: Syphidae Subfamily: Syrphinae	*Chrysotoxum derivatum**	Walker	Thin-banded meadow fly	2	2	208-225	1	1	–	–	–	NA	aphid predator	Nearctic
	Dasysyrphus sp.	–	Conifer fly	3	3	201-542	1	–	–	1	1	NA	aphid predator	–
	Epistrophe grossulariae	(Meigen)	Black-horned smoothtail	3	2	242-570	–	–	–	–	3	NA	aphid predator	Holarctic

*New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Diptera Family: Syphidae Subfamily: Syrphinae (continued)	*Epistrophe terminalis*	(Curran)	Bare-plated smoothtail	2	2	467-526	–	–	2	–	–	NA	aphid predator	Nearctic
	Eupeodes curtus	(Hine)	Comma-spot aphideater	3	2	325-519	–	–	3	–	–	NA	aphid predator	Holarctic
	Eupeodes flukei	(Jones)	Fluke's aphideater	1	1	220	–	–	1	–	–	NA	aphid predator	Nearctic
	Eupeodes lapponicus	(Zetterstedt)	Common loopwing aphideater	7	3	242-874	–	1	–	–	6	NA	aphid predator	Holarctic
	Eupeodes latifasciatus	(Macquart)	Variable aphideater	1	1	481	–	–	–	–	1	NA	aphid predator	Holarctic
	Eupeodes luniger	(Meigen)	Black-tailed aphideater	4	3	201-340	1	–	3	–	–	NA	aphid predator	Holarctic
	Eupeodes neoperplexus	(Curran)	Spot-headed aphideater	2	2	467-548	–	–	2	–	–	NA	aphid predator	Nearctic
	Eupeodes sp.	–	Aphideater	7	7	201-823	1	1	3	–	2	NA	aphid predator	–
	Melangyna arctica	(Zetterstedt)	Pollinose halfband	1	1	756	–	–	1	–	–	NA	aphid predator	Holarctic
	Melangyna guttata	(Fallén)	Variable duskyface	1	1	208	1	–	–	–	–	NA	aphid predator	Holarctic
	Melangyna labiatarum	(Verrall)	Bare-eyed halfband	2	2	242	1	–	–	–	1	NA	aphid predator	Holarctic

*New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Diptera Family: Syphidae Subfamily: Syrphinae (continued)	*Melangyna triangulifera*	(Zetterstedt)	Spotted roundtail	1	1	325	–	–	1	–	–	NA	aphid predator	Holarctic
	Melangyna umbellatarum	(Fabricius)	Bare-winged halfband	1	1	208	1	–	–	–	–	NA	aphid predator	Holarctic
	Melanostoma mellinum	(Linnaeus)	Western roundtail	8	7	214-921	–	1	2	1	4	NA	aphid predator	Cosmopolitan
	Meliscaeva cinctella	(Zetterstedt)	American thintail	3	2	208-242	2	–	–	–	1	NA	aphid predator	Holarctic
	Parasyrphus relictus	(Zetterstedt)	Boreal bristleside	1	1	214	–	1	–	–	–	NA	aphid predator	Holarctic
	Parasyrphus tarsatus	(Zetterstedt)	Holarctic bristleside	18	6	467-1176	–	–	12	–	6	NA	aphid predator	Holarctic
	Platycheirus albimanus	(Fabricius)	Three-tufted sedgesitter	5	2	202-632	5	–	–	–	–	NA	aphid predator	Holarctic
	Platycheirus amplus	Curran	Broadhand sedgesitter	8	6	194-897	1	–	6	–	1	NA	aphid predator	Holarctic
	*Platycheirus chilosia**	(Curran)	Bristlehand sedgesitter	2	2	887-897	–	–	–	–	2	NA	aphid predator	Nearctic
	Platycheirus granditarsis	(Forster)	Hornhand sedgesitter	6	2	214-235	–	6	–	–	–	NA	aphid predator	Holarctic
	Platycheirus groenlandicus	Curran	Greenland sedgesitter	8	4	519-887	–	–	1	3	4	NA	aphid predator	Holarctic
	Platycheirus hyperboreus	(Staeger)	Silvery sedgesitter	5	4	220-533	–	–	4	–	1	NA	aphid predator	Holarctic

*New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Diptera Family: Syphidae Subfamily: Syrphinae (continued)	*Platycheirus naso*	(Walker)	Tufter sedgesitter	10	9	208-887	1	2	4	2	1	NA	aphid predator	Holarctic
	Platycheirus nigrofemoratus	Kanervo	Black-legged sedgesitter	1	1	542	–	–	–	1	–	NA	aphid predator	Holarctic
	Platycheirus peltatoides	Curran	Keeled sedgesitter	5	4	208-548	1	–	3	1	–	NA	aphid predator	Nearctic
	Platycheirus podagratus	(Zetterstedt)	Variable sedgesitter	8	4	481-533	–	–	1	–	7	NA	aphid predator	Holarctic
	Platycheirus sp.	–	Sedgesitter	1	1	347	–	–	1	–	–	NA	aphid predator	–
	Scaeva pyrastri	(Linnaeus)	White-bowed smoothwing	1	1	467	–	–	1	–	–	NA	aphid predator	Holarctic
	Sphaerophoria abbreviata	Zetterstedt	Variable globetail	35	22	179-846	9	3	8	2	13	NA	aphid predator	Holarctic
	Sphaerophoria contigua	Macquart	Tufted globetail	1	1	526	–	–	1	–	–	NA	aphid predator	Nearctic
	Syrphus attenuatus	Hine	Yellow-margined flower fly	14	13	179-756	5	–	6	2	1	NA	aphid predator	Holarctic
	Syrphus ribesii	(Linnaeus)	Common flower fly	40	15	185-912	18	4	9	5	4	NA	aphid predator	Holarctic
	Syrphus sexmaculata	(Zetterstedt)	Six-spotted flower fly	1	1	340			1	–	–	NA	aphid predator	Holarctic
	Syrphus vitripennis	Meigen	Black-legged flower fly	10	7	185-406	7	1	2	–	–	NA	aphid predator	Holarctic

*New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Hymenoptera Family: Andrenidae Subfamily: Andreninae	*Andrena barbilabris*	(Kirby)	Mining bee	15	4	194-340	1	–	14	–	–	solitary	soil	Holarctic
	Andrena miranda	Smith	Mining bee	5	1	203	5	–	–	–	–	solitary	soil	Nearctic
	Andrena sp.2	–	Mining bee	1	1	325	–	–	1	–	–	solitary	soil	
	Andrena sp.3		Mining bee	1	1	495	–	–	–	–	1	solitary	soil	–
	Andrena sp.6		Mining bee	1	1	220	–	–	1	–	–	–	–	–
	Andrena thaspii	Graenicher	Mining bee	2	2	325-467	–	–	2	–	–	solitary	soil	Nearctic
Order: Hymenoptera Family: Andrenidae Subfamily: Panurginus	*Panurginus ineptus*	Cockerell		2	2	495-499	–	–	1	–	1	solitary	soil	–
Order: Hymenoptera Family: Apidae Subfamily: Apinae	*Bombus bohemicus*	(Seidl)	Ashton cuckoo bumble bee	1	1	689	–	–	–	–	1	parasite	parasite	Holarctic
	Bombus cryptarum	(Fabricius)	Cryptic bumble bee	13	11	214-912	1	5	3	2	2	social	undergr. hive	Holarctic
	Bombus flavidus	Eversmann	Fernald cuckoo bumble bee	4	4	470-798	–	–	1	1	2	parasite	parasite	Holarctic
	Bombus flavifrons	Cresson	Yellow head bumble bee	43	22	179-870	17	–	11	6	9	social	undergr. hive	Nearctic
	Bombus frigidus	Smith	Frigid bumble bee	39	18	195-870	14	15	4	2	4	social	abovegr. hive	Nearctic

*New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Hymenoptera Family: Apidae Subfamily: Apinae (continued)	*Bombus jonellus*	(Kirby)	White tail bumble bee	84	25	179-912	19	31	18	1	15	social	undergr. hive	Holarctic
	Bombus jonellus/frigidus	–	–	6	5	208-798	2	1	–	–	3	–	–	–
	Bombus kirbiellus	Dahlbom	High country bumble bee	18	13	369-823	6	–	10	–	2	social	undergr. hive	Holarctic
	Bombus melanopygus	Nylander	Black tail bumble bee	6	3	224-265	–	6	–	–	–	social	hive varies	Nearctic
	Bombus mixtus	Cresson	Fuzzy-horned bumble bee	10	7	201-369	1	7	1	–	1	social	hive varies	Nearctic
	Bombus neoboreus	Sladen	Active bumble bee	18	6	235-839	1	1	6	–	10	social	undergr. hive	Nearctic
	Bombus occidentalis	Greene	Western bumble bee	1	1	203	1	–	–	–	–	social	undergr. hive	Nearctic
	Bombus perplexus	Cresson	Confusing bumble bee	1	1	201	1	–	–	–	–	social	undergr. hive	Nearctic
	Bombus polaris	Curtis	Polar bumble bee	43	14	208-885	8	14	9	–	12	social	undergr. hive	Holarctic
	Bombus sylvicola	Kirby	Forest bumble bee	114	35	201-897	14	19	31	1	49	social	undergr. hive	Nearctic
Order: Hymenoptera Family: Apidae Subfamily: Nomadinae	*Nomada* sp.	–	Cuckoo bee	9	4	201-340	5	–	4	–	–	parasite	parasite	–

*New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Hymenoptera Family: Colletidae Subfamily: Colletinae	*Colletes impunctatus lacustris*	Swenk	Cellophane bee	29	4	499-526	–	–	29	–	–	solitary	soil	Holarctic
Order: Hymenoptera Family: Colletidae Subfamily: Hylaeinae	*Hylaeus annulatus*	(Linnaeus)	Masked bee	20	9	202-499	9	7	2	–	2	solitary	twigs	Holarctic
Order: Hymenoptera Family: Halictidae Subfamily: Halictinae	*Halictus rubicundus*	(Christ)	Sweat bee	7	2	201-203	7	–	–	–	–	solitary	soil	Holarctic
	Lasioglossum boreale	Svensson, Ebmer and Sakagami	Sweat bee	5	4	203-340	1	–	3	–	1	solitary	soil	Holarctic
	Lasioglossum comagenense	Knerer and Atwood	Sweat bee	13	3	201-340	12	–	1	–	–	solitary/ semisocial	soil	Nearctic
	Lasioglossum inconditum	(Cockerell)	Sweat bee	6	3	201-325	4	–	2	–	–	solitary	soil	Nearctic
	Lasioglossum tenax	(Sandhouse)	Sweat bee	48	3	201-208	48	–		–	–	solitary	soil	Nearctic
	Sphecodes sp.		Cuckoo bee	2	2	220-340	–	–	2	–	–	parasite	parasite	–
Order: Hymenoptera Family: Megachilidae Subfamily: Megachilinae	*Megachile circumcincta*	(Kirby)	Leafcutter bee	1	1	516	–	–	1	–	–	solitary	soil	Holarctic

*New state record.

Table A-1 (continued). Common names for flower flies taken from http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Habitat columns show number of specimens of each species collected in that habitat. Codes for syrphid fly larval habit: decay. org./water = decaying organic matter in stagnant water; decay. wood = decaying wood or sap. Codes for bee nesting habitat: abovegr. hive = aboveground hive; undergr. hive = underground hive.

Taxon	Species	Authority	Common name	# Specimens	# Sites	Elev. range (m)	Disturbed area	Lake	River	Shrub/Tree	Tundra	Sociality	Larval habit (flies) Nesting habit (bees)	Global range
Order: Hymenoptera Family: Megachilidae Subfamily: Megachilinae (continued)	*Megachile lapponica*	Thomson	Leafcutter bee	1	1	203	1	–		–	–	solitary	cavity	Holarctic
	Osmia nigriventris	(Zetterstedt)	Mason bee	2	1	225	–	–		–	2	solitary	insect holes/ wood	Holarctic
	Osmia tersula	Cockerell	Mason bee	2	1	225	–	–		–	2	solitary	wood/stem	Nearctic
	*Stelis nitida**	Cresson	Cuckoo bee	1	1	224	–	1		–		parasite	parasite	Nearctic

*New state record.

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